BIOSYNERGY Newsletter No. 6

Welcome to the sixth newsletter of the Integrated Project BIOSYNERGY on biorefineries, co-funded under the 6th Framework Programme for Research and Technological Development of the European Communities.

The increasing global concerns about the costs and impacts of fossil fuel consumption, is boosting the worldwide development and production of bioenergy and biobased products. This shift from fossil fuels to biomass feedstocks creates real opportunities. Using biomass for energy, fuel and industrial production has the potential to make an important contribution toward the sustainability of our agriculture, forestry, energy and manufacturing sectors.
If done with an appropriate technology and at the right scale the use of lignocellulosic feedstocks in an integrated biorefinery for the production of energy, fuels and chemicals results in the following positive effects:

- global warming emissions reduction;
- security of energy supply improvement;
- biodiversity protection;
- soil, water quality and overall environmental health protection;
- new jobs opportunities;
- new markets for farmers;
- rural communities development;
- environmental and industrial impacts on health reduction.

But, if biomass production is done in a wrong way, the whole process be unsustainable. Increased biomass production, (in particular if not lignocellulosic), could actually have a negative environmental impact. It might result in decreased biodiversity, water quality, soil health and wildlife habitat and on top of that the greenhouse gases emission reduction could even be negative.
If social and economic needs are not taken into account by policy makers and industries in the planning phase, the expanding biomass sector could increase pressure on alternate land use, jeopardize food security, and do nothing to improve the economic situation of rural regions.
Therefore, it is vital that biomass production and transformation is made in such a way that is environmentally, economically and socially sustainable and responsible.

In this context, the BIOSYNERGY project is particularly relevant; the main expected outcomes are:

- Technical, socio-economic and ecological European perspective of integrated refinery processes for the co-production of chemicals, transportation fuels and energy from biomass by performing integral biomass-to-products chain design, analysis and optimisation.
- Lab-scale development and pilot-scale demonstration of biorefinery-based composing sub-processes, i.e.: physical/chemical fractionation processes, thermo-chemical conversion processes, biochemical conversion processes, and chemical conversion and synthesis processes.
- Basic design of an innovative cellulose-ethanol based biorefinery process in which the residues are upgraded
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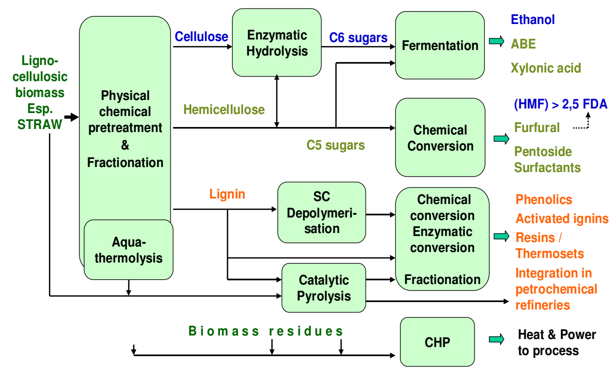

Fig.1: Product lines being considered in BIOSYNERGY

BIOSYNERGY update by work-packages

<u>**WP 1**: Advanced physical / chemical fractionation</u>

The subject of WP1 is the lab-scale experimental development and optimisation of technologies for physical and chemical pre-treatment and fractionation of biomass to convert its fractions into a wide range of added-value products making the integrated process more economically profitable and environmentally friendly.

The main achievements of Work Package 1 to date are:

- An extensive literature review on fractionation was completed,
- Distribution and full (bio)chemical characterisation of feedstocks: straw, wood and DDGS,
- The proof of concept of four fractionation technologies was completed,
- Simulation models for fractionation were constructed, and benchmarks for fractionation were defined and applied,
- Capital and operating costs of fractionation were determined on a comparative basis, for three fractionation technologies,
- The new enzyme development programme was continued,
- The performance of commercially available enzymes was characterised,

WP 2: Innovative thermochemical conversion

Work Package 2 aims at the valorisation of (residual) biomass for a wheat straw based 2nd generation bio-ethanol plant by innovative thermochemical processing concepts for value-added chemicals, fuels and / or materials. The concepts are self-sustainable with respect to heat demand, environmentally sound, and economically efficient. The main progress includes:

- Delivery of Proof-of-Principle for a hybrid staged degasification concept for biomass valorisation, consisting of a pressurised hot water pretreatment step followed by a bubbling fluidised bed pyrolysis, proven for beech, poplar, spruce, wheat straw and lignin
- Conversion of several feedstocks (see above) including DDGS to bio-oil using non-catalytic rotating-cone and bubbling fluidised bed fast pyrolysis technology
- Development of catalytic pyrolysis programme
- Successful fractionation of bio-oil in fractions for resin and wood preservatives production
- Theoretical and practical assessment of separation technologies for thermo-chemically derived product mixtures.

WP 3: Advanced biochemical conversion

This WP focuses on the development of advanced biochemical processes for conversion of sugars and lignin into value-added products or intermediates including higher alcohols, platform chemicals and functional lignin derivates. The main achievements to date include:

- ABE-fermentation: Suitable conditions for continuous one-step ABE fermentation on a xylose-based synthetic medium were defined. The ABE productivity was close to 0.5 g/L*h. However, continuous ABE production on wheat straw hemicellulose hydrolysates still need further improvement because of the presence of toxic compounds in the feeding medium. Various Clostridium strains were tested for ABE production using DDGS either as a sole carbon source or in combination with glucose. Besides, separation of ABE from fermentation broths by pervaporation or using rotating disc separator was demonstrated.
- Xylonic acid production from xylose: The capacity to convert xylose to xylonic acid was assessed in batch and continuous cultures on mixtures of glucose (or galactose) and xylose, and on acid-hydrolyzed DDGS or on pentose-rich wheat straw hydrolysate. Various parameters were determined (product concentration, productivity, selectivity) in order to compare performances of the different systems selected: bacteria, filamentous fungi and engineered yeast strains.
- Lignin to functional derivates: The reactivity was highly dependent on the lignin used. The potential processes that would produce lignins to be used as raw materials for the preparation of functional lignin derivatives have been identified. Such derivatives have been characterised, prepared at a kg scale and sent to partners in order to test potential applications.

WP 4: Innovative chemical conversion and synthesis

This WP develops various promising chemical conversion technologies for the valorisation of C5 and C6-sugars, lignin and thermo-chemically derived intermediates. Furthermore the WP addresses process analysis and development for the synthesis of final products from intermediates (furanics and phenolics chemicals) produced. Thusfar the main results include:

- Platform chemicals production and characterisation at laboratory scale:
- Lignin depolymerisation in supercritical CO_2 and co-solvent; the achievements in 2009 include a significant yield improvement by a better controlled reaction.
- Lab-scale reactor design to analyse furfural synthesis and kinetics from xylose: better understanding of side reaction allowed yield improvement to 85% (starting from xylose). Consolidated data were provided to WP6.
- Hydroxymethylfurfural production from glucose: improvement of yields has been achieved by the use of ionic-liquids.
- Lab scale synthesis of products from selected platform chemicals: production of FDA has been performed with at minimum yields of 90% using processes developed by partners. The use of FDA in polyesters has been studied.
- Pentose valorisation as raw materials for surfactants; a green technology was developed at lab-scale to convert pentoses from WP1 to surfactants. The Proof of Concept has been delivered and data was provided to WP6.
- Literature overview of innovative membrane reactor concepts for potential use in product recovery.

Fig.2: Abengoa ethanol Plant in Salamanca

WP 5: Conceptual design biorefinery validation pilot-plant of Abengoa in Salamanca

The goal of this WP is the conceptual design of an innovative biorefinery facility at the existing BCyL cellulose ethanol demo-plant of Abengoa Bioenergy in Salamanca (Spain). The design of the biorefinery facility will include integrated physical/chemical fractionation processes coupled to advanced biochemical or (thermo-)chemical conversion processes. The targeted output of the facility includes upgraded bio-products (chemicals and/or materials), refined transportation biofuels as well as power and/or heat.

The progress achieved up to date includes:

- Extended component database physical & chemical properties for process design in Aspen Plus
- Preparation of integrated model for the BCyL lignocellulose to bio-ethanol process scaled-up to commercial scale of 400 ton/day of wheat straw
- Extended base case model simulating the BCyL plant with the addition of:
    - Biomass fractionation
    - C5 fermentation
    - On-site enzyme production
    - Lignin valorisation
- Base case operational and capital costs
- Economic model to evaluate different design concepts and scenarios.
- Conceptual design of a 100% Ethanol Biorefinery facility, which integrates both thermochemical and biochemical ethanol production processes
- Operating and capital expenses of the 100% Ethanol Biorefinery concept
- First Aspen model for an integrated biorefinery that produces ethanol from cellulose and two bioproducts from hemicellulose and lignin fractions

The starting point for the conceptual design is Abengoa's cellulose to bioethanol demonstration plant at Babilafuente (Salamanca, Spain). The pilot plant is located next to a wheat ethanol production plant and has a production capacity of 5 Million litres of cellulose ethanol per year. The cellulose ethanol demonstration plant was successfully started up in September 2009 and is fully operational.

WP 6: Integral biomass-to-product chain design, analysis and optimisation

The objective of this WP is to perform a comprehensive (technological, economic, environmental and socio-economic) assessment and optimisation of bio-refinery chains from feedstock to end-products.
The ultimate goal of the WP is to identify the most promising bio refinery chains within a future European bio-based economy based on energy efficiency, environmental performance and cost, and to quantify the overall environmental effects of these chains, as well as the possibilities for their integration with conventional petrochemical oil refineries.
The bio-refinery concept is relatively new, and identifying the most promising chains is one of the major difficulties facing Europe. There are so many options and process routes that a methodology needs to be established to identify those that are most promising. The initial focus is placed on cellulosic ethanol based bio-refinery cases, to create maximum added value for the project in close coordination with WP5.
Quantification of the environmental and socio-economic effects of biomass production, biomass transportation and its conversion in integrated bio-refinery processes to different products, based on life-cycle considerations, will also be included. Examples of the environmental effects to be considered are: global warming potential, acidification, eutrophication, ozone depletion and cumulated primary energy and material demand.
The work flow is illustrated in Figure 3 .

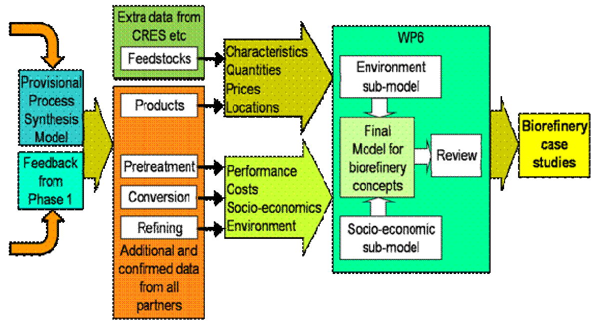

Figure 3 – WP6 work flow

The progress so far includes:

- Creation and the validation of a process synthesis methodology and modelling tool to identify the optimum process chain design; includes process model, socio economic model and environmental assessment
- Methodology consists of three steps:
    - Process chain generation (Process Synthesis)
    - Process modelling
    - Process chain comparison (MCDA)
- Definition of the main structure of the LCA model and collection of data
- 11 complete biorefinery concepts have been selected and modeled.
- An additional 15 biorefinery concepts to be included in final results

Final methodology will allow the analysis and comparison of many more complete concepts than the 26 chosen for the project, as the models have a high level of flexibility

WP 7: Demonstration at pilot scale

The pilot scale demonstration in this WP includes the use of pilot-scale facilities to a) produce samples of bio-based intermediates for the lab and bench-scale technology developments in WP's 1-4 and b) to examine the potential for scaling-up the developed technologies. The main progress to date includes:

- Production and distribution of 160 kg pre-treated (steam explosion) wheat straw from the York plant in the US by ABNT to be used as raw material for downstream technology developments.
- Both pre-treated straw, raw straw (1.25 tonne), and DDGS (3 tonnes) were distributed to the partners early 2008.
- Delivery of 20 kg of dry corn stover stillage from York plant to A&F in January 2009.
- Production of 20 tonnes stillage (lignin rich residue from straw) from the BCyl cellulose ethanol demonstration plant in Salamanca, Spain by ABNT to be used as raw material for downstream technology developments by Aston, ECN, BTG, A&F and TUD. The transport, dewatering and drying was performed by ECN at the end of 2009, resulting in about 450 kg (85-90% dry weight) lignin rich residual Dry Distillers Biomass (DDB).
- Production of 280 kg pyrolysis bio-oil from 500 kg pine wood – for downstream technology development (a.o. resins production by Chimar) – in a fast pyrolysis installation.

Scale-up of selected lab scale technology developments to pilot scale will take place from 2010 onwards depending on the R&D progress made.

WP 8: Training and knowledge dissemination.

The objective of WP8 is to ensure the two-way communication of the project with the outside world. This includes general promotion of project results, exchange of views and information with external stakeholders, training of persons in relevant industries and institutions, dissemination of policy options and recommendations to national and European stakeholders and policy-makers.
During summer 2009, in order to boost the dissemination of project results, three workshops were organized to present the BIOSYNERGY preliminary results obtained during the first half of the Project (2007-2008):

1. *"Adding Value to the Sustainable Utilization of Biomass",* June 12th 2009, Ghent, Belgium. During this workshop the first version of the Biosynergy Biorefinery Training Course was presented. The workshop was organized as a side event of the Fifth International Renewable Resources & Biorefineries Conference.
2. *International Biorefinery workshop*, 22nd June 2009 in Madrid, Spain. Organized by Abengoa Bioenergía Nuevas Tecnologías, in collaboration with Genoma España, IDAE and CIEMAT. The event was co-organised and sponsored by the BIOSYNERGY Project.
3. *Advanced Biorefinery Concepts and Technologies workshop*. 2 July 2009; Hamburg, Germany. The workshop was organized as a side event of the 17th European Biomass Conference & Exhibition 'From Research to Industry and Markets'.

Full workshop reports, presentations etc. are available for downloading at the project website: www.biosynergy.eu.

Beside the workshops, the following main results were achieved in 2009:

- Continuous enrichment and updating of the project website www.biosynergy.eu
- IT e-learning web-module delivered, more lectures are expected in 2010
- Road show delivered; including the following items:
    - Biosynergy video: available on the Biosynergy website, on YouTube http://www.youtube.com/watch?v=xL_fVnKYjrg&feature=related and other sources
    - Biosynergy poster
    - Biosynergy folders: dissemination material that includes partner profiles, newsletter, brochure
- 2 newsletters
- Scientific publications and presentations at various international events (conferences, workshops)

Legal notice

The total budget of BIOSYNERGY is 13.4 M€. The project receives financial support from the Sixth Framework Programme for Research and Technological Development of the European Communities (Contract No. 038994 / SES6). The Communities' financial contribution is up to 7.0 M€ in the form of a grant to the budget.
BIOSYNERGY started on 01.01.2007 and will last for four years, until the end of 2010.

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Fig. 4: Biosynergy consortium after the visit to Abengoa 2nd generation ethanol plant in Babilafuente (Salamanca, Spain)